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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PLATE X

Mitchell motion picture camera attached to the 10-inch Cooke refractor.

PLATE XI

Motion Pictures of a Lunar Eclipse.

Journal of the Royal Astronomical Society of Canada, 1938.

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Vol. XXXII, No. 9 NOVEMBER, 1938 WHOLE No. 278

MOTION PICTURES OF A TOTAL LUNAR ECLIPSE

BY WILLIAM H. CHRISTIE AND WILLIAM MILLER

(with Plates X and XI)

THE total lunar eclipse of May 21st, 1938, afforded an excellent opportunity to take motion pictures of the event on the Pacific Coast because totality occurred close to midnight in these longitudes. Since it will be many years before a similar opportunity presents itself here, we decided to attempt to make a film of the event. In this endeavor we were successful and since a description of the technique employed may be useful to others in similar attempts, we have decided to publish it in some detail.

Owing to several factors our direct knowledge of the problem had to be gained in the few hours between sunset and first contact, when the moon was in the penumbra of the earth's shadow, an interval only just sufficient for our purpose. Fortunately for us our preliminary guesses as to the requirements were close, but had we the opportunity to do it over again doubtless we could improve the results.

The telescope used for these pictures was the 10-inch, f 4.5, Cooke photographic refractor. The color curve of the objective of this instrument is fairly flat in the blue-violet region but drops steeply in the red. The light which is refracted around the limb of the earth and faintly illuminates the eclipsed moon, is quite red in color—a coppery-red describes it fairly accurately. Hence, if the eclipsed portion of the moon is to be shown on the photographs a red-sensitive film must be used. Accordingly Eastman Panchro-

matic Super X standard motion-picture film was used in conjunction with a No. 29, × 12, filter which limited the light to a narrow region of the spectrum in the red.

The exposure time for such a combination of lens, film and filter is about 1/50 second for the uneclipsed moon and five seconds for the earth-limb lit portion in this last eclipse, which was decidedly dark as lunar eclipses go. The exposure time necessary for other eclipses must be estimated when the time comes, but the figures here given may be of some help as a guide.

The camera used was a standard Mitchell motion picture camera which was kindly loaned to us by Paramount Pictures Inc. The

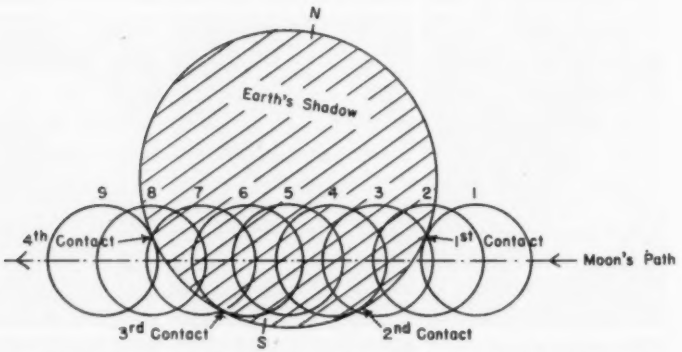


Fig. 1.—Path of the Moon through the Earth's shadow, May 21, 1938.

mounting of the camera on the telescope is shown in Plate X. This camera is a beautiful piece of mechanism and possesses a device which makes it very valuable for this type of work. The outstanding feature is that the mechanism and film reels may be racked sideways on the camera base across the lens turret, which remains stationary, thus bringing a finder with variable magnification into the former position of the film aperture. The operator is thus able to see exactly what is included in the frame and to center accurately on the object being photographed, since the lens used is the same as that being employed in forming the image on the film.

The ordinary motion picture camera exposes twenty-four frames

per second; it was necessary, therefore, to increase greatly the intervals between exposures. The film speed was reduced accordingly to one foot per minute, a ninety-times reduction. To show the final film from first to last contact takes a little over two minutes.

The camera was clamped to a wooden, shelf-like support which, in turn, was firmly bolted at right angles to the plate base of the telescope, the film aperture being carefully centered on the axis of the lens. A small synchronous motor with a reduction gear drove the operating crank by means of a round belt running over a large grooved pulley attached directly to the slow-motion hand crank which exposes one frame per revolution. The crank was left in place in case any trouble developed with the drive. To attempt to turn the crank uniformly by hand at such a low speed as one revolution in a little less than four seconds would be next to impossible and uniform motion of this crank is necessary to obtain uniform exposures. The exposure time in this type of camera is varied by increasing or reducing the angle between the two segments of which the rotary shutter is composed. This may be done while the camera is in operation, and during the eclipse we slowly opened the shutter as second contact was approached until the exposure was at its maximum of about two seconds. One frame was exposed for about five seconds during totality, giving us a well exposed image of the eclipsed moon (5, Plate XI). After third contact the shutter was slowly closed again.

The size of a standard motion-picture frame is approximately $\frac{5}{8} \times \frac{7}{8}$ inch and the image of the moon formed by the 10-inch refractor is about $\frac{3}{8}$ inch in diameter, a very satisfactory relation of dimensions if the telescope is to be centered on the moon during the eclipse, as was done in this case. A more realistic effect would be obtained, however, by guiding on the sub-solar point; the moon would then appear to cross the earth's shadow, the latter remaining stationary on the screen. To obtain this effect it would be necessary to use an image of the moon about $\frac{1}{8}$ inch in diameter. It is probably better, therefore, to photograph the eclipse with the larger image and, if the other effect is desired, to obtain it by printing the positive by projection and moving the projector, or positive film carrying

mechanism, so that the shadow remains centered on the frames of the positive.

For photographs such as these some means for accurate guiding on the moon should be provided. Two pairs of cross wires separated so that they are tangent to the moon's limb would be satisfactory; another effective method might be to use a diaphragm in the focal plane of the guiding telescope with four projections which would just make contact with the edge of the image. To guide on the sub-solar point it would be sufficient to guide on a star near the moon's path, for this would mean a drift of the image of the earth's shadow of only two minutes of arc in four hours.

The elements of this eclipse were, for Pacific Standard Time:

Moon entered penumbra	May	13^d	21^h	$44^m.3$	
Moon entered umbra		13	22	56 .6	(1st Contact)
Totality began		14	00	18 .1	(2nd Contact)
Middle of totality		14	00	43 .5	
Totality ended		14	01	09 .0	(3rd Contact)
Moon left umbra		14	02	30 .7	(4th Contact)
Moon left penumbra		14	03	43 .3	

The path of the moon through the earth's shadow is shown in Figure 1. The numerals above the circles representing the position of the moon refer to the photographs on Plate XI.

In conclusion we wish to express our sincere appreciation to Paramount Pictures, Inc., for their generosity in providing us with the camera and film with which these pictures were taken.

Carnegie Institution of Washington
Mount Wilson Observatory.
June, 1938.

A NEW SUN-EARTH-MOON MODEL

By W. G. Colgrove

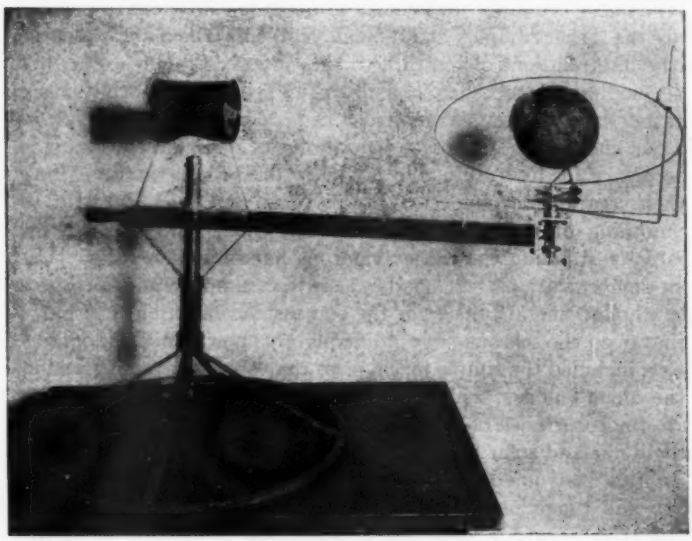
A new model of the Sun-Earth-Moon System recently designed by the writer and built at the University of Western Ontario for its Department of Mathematics and Astronomy.

IN designing this mechanical instrument we were fully aware of the many attempts that had been made in this field to demonstrate the rather complex and difficult problems which are presented by the interrelations of the three bodies involved. Our experience in developing several other original aids to astronomical study made us rather careful about such matters as proportions and gear ratios, and our knowledge of some of the failures of other inventors made it necessary for us to refuse to follow in the beaten track. Many of their creations are unnecessarily involved and even fantastic, to say nothing of their frail construction, which renders them incapable of standing the rather vigorous handling of regular classroom demonstrations. It has been quite common practice to provide a hollow metal sphere for the sun instead of an electric light, so that even the seasons are not adequately shown, and seldom has anyone included the simple mechanism that produces the regression of the moon's nodes, which is so necessary to adequately demonstrate the recurrence of the phases of the moon and the repetition of the lunar and solar eclipses in the Metonic and Saros cycles.

In this instrument we present a unique combination of simplicity and ruggedness, together with compactness of design and comparative accuracy, only one approximate proportion being included, that of the diameters of the earth and the moon. We have learned that proportion is not essential and its absence is no handicap to the demonstrating value of the instrument. The problem of distances was solved by the limitations of portability and the space in one's car when conducting extension lectures with the instrument. The matter of diamaters of the three bodies was determined by size of the electric lamp and the requirements of classroom work. The complete model is 4 feet long, 2 feet wide

*Reprinted by permission, from The Canadian Science Digest.

and 2½ feet high and can easily be carried on the rear seat of a car. It weighs only a few pounds. The earth is an ordinary globe, 6 inches in diameter, on which the usual features are easily visible and on whose surface solar eclipses are clearly shown. The size of the moon is made proportional to that of the earth for obvious reasons, and the sun-lamp is housed in a cylindrical reflector. The moon, of course, is much too near the earth, but its distance was



The Sun-Earth-Moon Model.

determined by our desire to show both the umbra and penumbra of the moon's shadow on the earth during solar eclipses and to keep the moon's orbit within the 2-foot limit of the base. These requirements made it necessary to greatly increase the inclination of the moon's orbit so that the moon's shadow would miss the earth and the earth's shadow would miss the moon some of the time. This proved to be valuable, for, on account of the rather large diameter of the earth, we can provide a half dozen consecutive solar

or lunar eclipses, so that the student can easily grasp these important phenomena without our revolving the earth many times to demonstrate widely separated eclipses. If we insisted on a model earth commensurate with the nine-inch radius of the moon's orbit it would be necessary to reduce the earth's diameter to ¼ and the moons to 1-16th inch, but these could not be observed by a class, to say nothing of the larger audiences that attend extension lecture-demonstrations. This lack of proportion may seem a handicap, but the operation of the instrument will immediately prove its very real value.

The design of the mechanism with its gear ratios has required considerable time and ingenuity and its present compact appearance will doubtless commend itself to all who understand and appreciate mechanical assembly. The main column or central vertical axis is a rigid, tubular structure attached to a sturdy fabricated iron base with rubber protectors beneath; at its top is a strong electric lamp, to act as the sun, whose light is constantly directed toward the earth by a reflecting hood which rotates around the stationary sun while the earth makes its annual revolution. This fixed sun-lamp has a wire equator attached so that the aim of the sun-spots, when present, may be indicated and understood through the recurring seasons of their period, and it will be quite apparent that during the Spring the equator arches upward and in the Fall it curves downward so that the effect of the sun-spots is almost nil, but during the Summer and the Winter seasons many of the spots aim directly at the earth and by their combined ultra-violet radiation and magnetic energy cause a variety of unusual disturbances in the earth's atmosphere and in our instruments of communication. The sun's rotation, however, soon carries the spots away from their earth-aim and their influence is directed into space. Just beneath the sun-lamp there is a graduated setting circle marked with degrees and minutes, as well as the months by which to show the heliocentric positions of the moon and planets and the monthly positions of the earth as it revolves around the sun. To this stationary vertical axis we have also attached the main driving gear meshed with a smaller gear fixed to the communicating shaft, which is carried in the hollow horizontal arm to convey the power to the unique train of gears in the open aluminum box beneath the earth. In this box are

three spur gears which engage the angle and worm gears to provide the various motions required. The result is eight-fold—a slight movement of the operating handle produces the revolution and the rotation of the earth, the revolution and rotation of the moon, the rotation of the earth's axis and the reverse rotation of the moon's orbit, the gradual ascent and descent of the moon on its arm to follow its orbit and the apparent rise and fall of the equator of the sun as observed from the earth during each revolution. The earth's rotation is reduced to only 26 times, the moon's revolutions to 6 times and the moon's orbit to 1-6 time for each revolution of the earth. This is done so that a class or audience may easily see what transpires. Just above this gear box will be found another graduated setting circle marked with hours and minutes, as well as the signs of the zodiac, by which to find the positions of the sun and the planets in right ascension and the constellations which form their background. This model demonstrates a great variety of atronomical phenomena connnected with the Sun-Earth-Moon system. A slow counter-clockwise movement of the handle, with many stops in the course of a revolution of the earth, will cause the following demonstration to be easily made and numerous explanations to be readily understood:

The three important planes—Horizon, Equator and Ecliptic, and their relations and functions.

The two graduated setting circles—the one beneath the sun for showing heliocentric positions such as the earth's longitude, the longitude of the earth's perihelion, the position of the line of apsides, and the earth's and sun's positions at any time. The other, below the earth, is for showing the R. A. of the planets as given in THE OBSERVER'S HANDBOOK, and the constellations of the zodiac where they are to be found at any time.

The period and velocity of rotation of all three bodies, day and night; the length of shadows, the apparent rising, culmination and setting of the sun, moon, planets and stars.

The inclination of the equators to the ecliptic, with the consequent direction of the axes, the advance of the seasons, the harvest moon, the midday night, the midnight day, the zones and the effect of solar radiation.

The sun's equator and the aim of the sun-spots, when present, on its surface. Their effect on atmosphere and communication.

The eccentricity of the orbits and its effect on distance, sun's radiation, tides and eclipses.

The inclination of the orbits to the ecliptic.

The sidereal period of revolution of earth and moon and the synodic period of the moon.

The lunar apogee and perigee, the nodes and their regression, the moon's phases and librations in longitude.

The elongation, conjunction, quadrature and opposition of the moon, as well as the positions where perturbations take place.

Eclipses of the sun and the moon—both partial and total.

Why the people in the southern hemisphere see the sun and the moon in the northern sky.

Why their seasons are the reverse of ours.

Why we have more and longer days in Summer than in Winter.

Why the sun is high in Summer and low in Winter.

The reason for and period of twilight.

Why the sun goes north at night.

Note: The audience is out in space and should imagine itself, for the observations, to be at the centre of the horizon plane where the pin marks our latitude.

The author suggests the name *Sotellunium* for the Sun-Earth-Moon model.

2 Christie St.,
London, Ontario.

ERNEST WILLIAM BROWN*

November 29, 1866-July 22, 1938

By Ida Barney

As long as the accurate position of the moon is of importance to men either for practical reasons or for scientific research the name of Ernest William Brown will be remembered and held in the highest esteem. For nearly fifty years he worked on the problem of the motion of the moon, beginning his studies when a student at Cambridge, England, and continuing his work up to a few days before his death. His remarkable accomplishment in this particular field of science placed him in the front rank of those mathematicians and astronomers who have developed the subject of gravitational astronomy, since Newton laid the foundations more than two centuries ago.

In 1919 the "Tables of the Motion of the Moon" were issued by the Yale University Press in three volumes containing some 660 pages of tables and explanations for their use. This was Professor Brown's great work, and in it he attained a degree of accuracy far beyond anything previously reached by workers in this field. These tables represented the main part of his scientific work for some thirty years. This period might be divided into two parts, the first extending up to 1910 when he completed the work on his lunar theory, and the second part covering the ten years during which the actual construction of the tables was under way.

The first of his long series of publications on the lunar theory began about 1891, when Professor Brown came to the United States to become an instructor of mathematics in Haverford College. In 1896 he published his "Introductory Treatise on the Lunar Theory," intended to be an elementary textbook, but which nevertheless showed his able mastery of the whole field of lunar theory, all the more remarkable because at that time he was not quite thirty years old. He had nearly completed this theory by 1907 when he was appointed Professor of Mathematics at Yale University.

*Reprinted by permission, from the November number of *The Sky*.

The actual construction of the tables was the next task at hand. Yale University undertook the cost of their calculation and printing so that prompt publication was made possible. Professor Brown showed his originality no less in the methods used in the making of the tables than he had done earlier in his work on the theoretical side. Also he was fortunate in having as his chief computer during these years Dr. H. B. Hedrick, who assisted greatly in constructing the tables most efficiently, and making them correct to a high degree of accuracy. Since their publication the tables have been tested by comparisons with observations in various ways, and each test has only served to show that their accuracy is indeed as great as had been estimated theoretically.

After the publication of the lunar tables Professor Brown's scientific activity covered a wider field, although he still devoted much time to problems connected with the motion of the moon. Always attracted by difficult problems and seeking new methods, he published noteworthy papers on the Trojan Group of Asteroids, on the motion of the Eighth Satellite of Jupiter, and on the more general problems in the theory of planetary motions. Most of his work on this last subject has been collected in a treatise "Planetary Theory" written with the collaboration of Dr. C. A. Shook.

During the years that Professor Brown was a member of the faculty of Yale University he taught a large number of students. Many of the students carried away from his classes a lasting impression of the laws of mechanics because of his individual methods of illustrating fundamental principles. The graduate students received from his teaching and from personal contact with him inspiration as well as excellent training for future scientific work.

The rate of rotation of the earth was a problem in which Professor Brown was deeply interested during the latter years of his life. In 1926 he published a paper "The Evidence for Changes in the Rate of Rotation of the Earth. . . ." The evidence for these changes he found in his comparison of the differences between observation and theory in the longitudes of the moon and the sun. It was in connection with his study of this problem that he took up his occultation campaign and his further discussions of lunar observations.

His occultation campaign included the gathering together and

reducing of occultations observed by all astronomers, both amateur and professional, and was carried through with the able assistance of Dr. Dirk Brouwer. This brought Professor Brown into contact with many persons outside of the limited circle of his scientific colleagues and gave mutual pleasure to both sides.

It was this occultation program particularly that led to his attendance at the meetings of the American Association of Variable Star Observers, and so gave many amateur astronomers the opportunity to know him and to appreciate his interesting personality. He greatly enjoyed attending the meetings of the numerous societies to which he belonged, and did this whenever possible. Moreover he never failed to contribute something to any gathering at which he was present, and to make it more worthwhile by his presence. Many of the societies recognized his ability in this direction by making him their presiding officer. He will be greatly missed in the future, especially by those who have for many years enjoyed his kindly wit and keen interest in the affairs of the world about him.

Between the years 1898, when he was elected Fellow of the Royal Society, and 1937, when he received the Watson Medal of the National Academy of Sciences, the scientific world bestowed on Professor Brown numerous honours and awards. As chief among these may be mentioned the Gold Medal of the Royal Astronomical Society in 1907 and the Royal Medal of the Royal Society of England in 1914. He received all these honours in his own modest way and treated any reference to them most casually; thereby showing as certainly as he did by his scientific work that he was indeed a great man.

Yale University Observatory,
New Haven, Connecticut.

THE SIXTIETH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY

By J. F. Heard

The regular summer meeting of the American Astronomical Society was held this year at the University of Michigan, Ann Arbor, September 14-17. The interesting arrangements and the excellent program resulted in a very good attendance of members and guests.

President R. G. Aitken was in charge of the meeting. In a brief address at the opening session Dean Clarence S. Yoakum welcomed the visitors. During the sessions forty-four papers were presented, ranging in subject matter from ancient Chinese astronomy to the discovery this summer of two new satellites of Jupiter. If any subjects may be said to have received especial attention they were eclipsing binaries, bright-line stars, nebulae with emission spectra, the aluminizing of telescope mirrors and colour photography of planets. Discussion on some of these topics waxed quite spirited.

During the business session the president announced a bequest from the late Professor E. W. Brown of $5000 to be set aside towards eventual publication of complete papers by the Society.

The well-known Michigan Union housed most of the visitors and provided convenient and agreeable headquarters. Meetings were conducted in the very beautiful new building of the Rackham Graduate School.

On the social side the arrangements of our hosts could not have been surpassed. On Thursday Mrs. Curtis and the ladies of the Observatory staff entertained the women guests of the meeting at luncheon in the Women's League. In the evening, after a tour of spots of scientific interest on the campus, Mrs. Curtis and the ladies of the Observatory staff were at home to the guests at the Observatory residence. On Friday evening the regular Society dinner was held at the Union. A feature of this function was the presentation by the trustees of the MacGregor fund to the astronomical library of the University of Michigan of a number of rare old books and manuscripts, including first editions of works of Galileo and Copernicus.

Saturday, the concluding day of the meeting, was devoted to a

visit to the McMath-Hulbert Observatory where the members had the opportunity to view the equipment and results of this unique institution and were guests at a very fine luncheon at the home of Mr. and Mrs. McMath.

Canadian visitors to the meeting included J. S. Plaskett, C. A. Chant and Mrs. Chant, Helen S. Hogg, Shirley Patterson, Ruth Northcott, J. F. Heard and Mrs. Heard. All of us enjoyed meeting our American colleagues once more, and we express our gratitude to our hosts at the University of Michigan and at the McMath-Hulbert Observatory for a thoroughly delightful and profitable meeting.

David Dunlap Observatory,
Richmond Hill, Ontario.

THE CONCEPT OF UNIFORMITY*

By Frederick H. Seares

MOST of these deficiences and dissatisfactions appear against the background of the old materialistic scheme. To-day a cleaner outlook is before us. It is too soon yet to estimate intellectual and emotional reactions; but certainly science as a mechanism involving the ultimate in indivisibles is one thing, and science as a momentary vision of man's fragmentary experience with an eternal mystery is quite another. On the older view, the machine had to be patched up whenever anything new appeared; and scrapped completely, if something really important happened—like relativity. The natural inference was that scientists were bad engineers because they made such poor guesses about nature's machinery. Then, there was the ruthlessness of the thing. To-day, however, changes mean only changes in symbols, which may be anything, if only they fulfil their symbolic function. The way is thus open to imaginative effort; and hence it is we put something of ourselves into the stars, so much so that at each stage a portion of accident appears in the vision—the accident that a Newton or an Einstein lived as he did, at a certain time, endowed with certain intellectual modes and imaginative qualities that shaped the vision to a pattern within the individual personality; it must never be forgotten that the symbols we use we ourselves create. As Poincaré insisted, for any set of facts we may find many laws, not all equally convenient, however; and, I repeat, the truth we know is in the fitness of the symbols. The imaginative effort in creative science, again to repeat, is therefore kin to that in other fields. By thus narrowing the gap between scientific and other experience science is brought closer to life. To quote again from Lucas,[1]

> The Science of the nineteenth century seemed to expel Poetry with a brandished test-tube; the Science of the twentieth century reopens the door to her with a bow.

[1] Proceedings, Royal Institution of Great Britain, vol. 29, p. 102, 1935; also The Decline and Fall of the Romantic Ideal, p. 143, Camb. U.P., 1936.

*The Editor takes the liberty of printing the closing section of a finely-printed booklet entitled "The Concept of Uniformity", by Frederick H. Seares, Assistant Director of the Mount Wilson Observatory, being the Elihu Root Lecture delivered April 19, 1938, under the auspices of the Carnegie Institution of Washington.

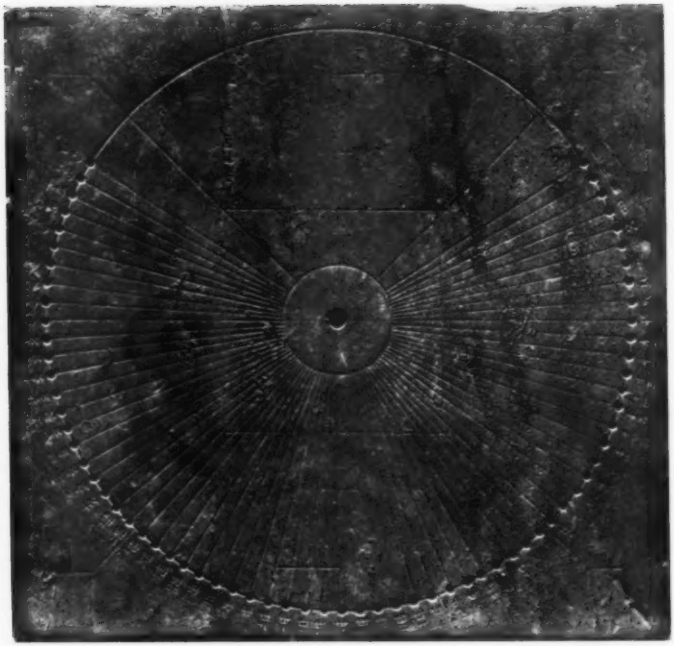
If the symbols of science are abstractions, they are at least symbolic; and yet if abstractions, they are not likely to provide directly either salvation for souls or a twentieth-century ethics that will resolve the ills of an embittered and disillusioned humanity. Nevertheless, the enrichment of the outer physical world by the rhythmic pattern revealed by science is by no means to be overlooked as a way toward enduring satisfactions; indirectly science may at least mould our sense of values. And then besides, in the phrasing of long ago,[2]

> I summon'd nature: pierc'd through all her store,
> Broke up some seales, which none had touch'd before,
> Her wombe, her bosome, and her head
> Where all her secrets lay a bed
> I rifled quite, and having past
> Through all the Creatures, came at last
> To search myselfe, where I did find
> Traces, and sounds of a strange kind.

What seems to emerge, therefore, is that science, to an unsuspected extent, is a reflection of human traits; that it is also a conscious creative effort to find fitting symbols which will make the physical world in some sense intelligible to our searching minds. Through some impulse within us, the effort goes on endlessly as a kind of pageant of aspiration. Science, concerned only with matters that find universal assent, must accept the changing symbols for what they are. Philosophy, with such aids as may be needed, is free to seek for deeper meanings. The old mechanism which arose from the confusion of symbol with what it symbolized is gone, and with it should also be gone the sense of futility that so long obsessed the minds of those who would assess the achievements of science in terms of spiritual calm.

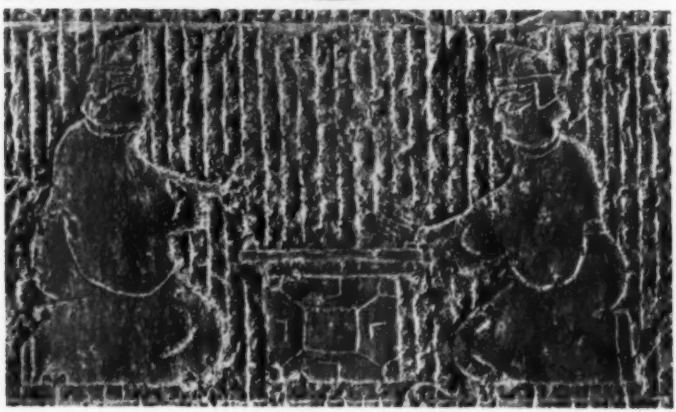
[2]Henry Vaughan, Silex Scintillans, 1650.

PLATE XII



A plane Chinese sun-dial of the Former Han period in the Far Eastern Collection of the Royal Ontario Museum.

A



B

A. Bronze mirror of probably the third century B.C. Besides the T.L.V. designs there are cloud-like groupings which may be Constellations, for they are not arranged symetrically. Two dragons encircle the central knob which may be accepted as denoting the sun-dial gnomon. An inscription of eight characters, expressing a lucky wish, fill the sides of the central square. Diameter 5¼ inches.

B. Section of stone frieze from Hsiao-t'ang Shan shrine, Shantung, dating about A.D. 128. The two men appear to be playing chess, and the design on the pedestal of the table is similar to that of the sun-dial.

COMMUNICATIONS
FROM THE
DAVID DUNLAP OBSERVATORY
Number 3

AN ANCIENT CHINESE SUN-DIAL

By W. C. White and P. M. Millman

(with Plates XII-XIV)

I. THE HAN DYNASTY SUN-DIAL.

THIS stone sun-dial, which Chinese and Western scholars accept as unquestionably of the third century B.C. was found in an excavation near Old Lo-yang, Honan, in 1932. It was brought to the writer by a native of the locality who had had direct participation in its excavation from an ancient tomb. He did not know what it was, neither did any of the Chinese scholars who saw it, for no one had seen such an object before. The late Dr. Liu Fu, a brilliant Chinese scholar and archaeologist, saw an ink-squeeze of the dial and recognized it as similar to one which had been in Viceroy Tuan Fang's collection (Fig. 1). He began investigating, and published the results of his study in a monograph called "A sun-dial of the Western Han period" (206 B.C.-A.D. 25). Before his study was completed he came across evidence of the existence of a fragment of a third dial (Fig 2) which had been found together with pottery measures said to be of the Ch'in Dynasty (221-206 B.C.). The form of script of the figures on the three dials is identical, and is the style which was common to the Ch'in Dynasty (220 B.C.-206 B.C.) and the Western or Former Han Dynasty (206 B.C.-A.D. 25).

The following table gives the main geographical particulars of each dial.

Where found	*Longitude*	*Latitude*	*Located at present*	*Dia. of circle*
A. Old Lo-yang, Honan	112°42′	34°40′N.	R.O.M.A.	250 mm.
B. Kuei-hua, Shansi	112°	41° N.	unknown	234 mm.
C. Yu-yü, Shansi	112°13′	40°10′N.	unknown	unknown

The fact of three dials of the same kind being found in proximity, points to a normal type for common use in that area some time

about 200 B.C. It should be noted that the measurements of dial B were given by Dr. Liu from a rubbing that had been remounted.

Dial A is a flat rectangular slab of grey limestone, about eleven inches square and an inch thick, with a diagram on one surface

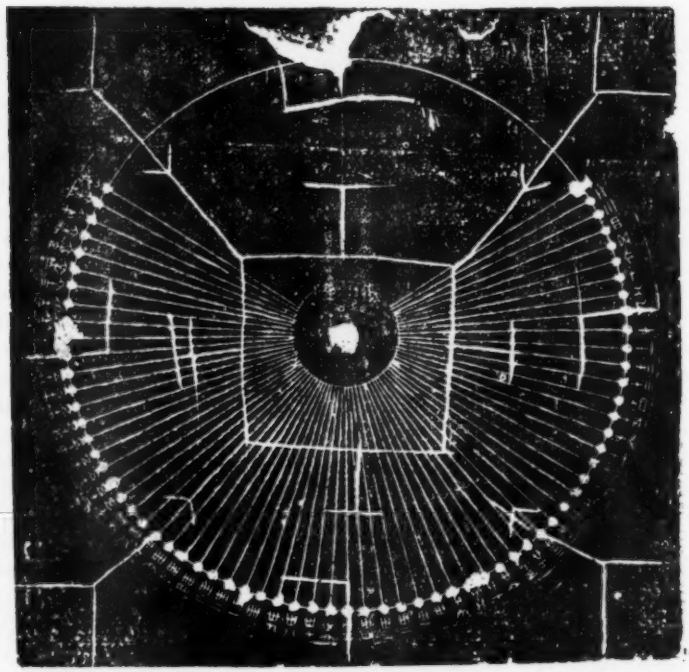


Fig. 1.—Ink-squeeze of stone sun-dial (B) formerly in Viceroy Tuan Fang's Collection, on the present location of which is unknown.

only (Plate XII). The gnomon is missing and there is no base, though it is assumed the dial would be tilted on a base. A circle about ten inches in diameter is graduated for 100 sections with radii lines numbers 1 to 69 incised from the circle to the centre, number 35 being due north if the dial should be tilted from the south, or

due south if a double gnomon should be used. Dr. Liu states that the diameter of this circle would probably be the length of the foot measure at the time the dial was made, and gives this as additional evidence for a Western Han attribution.

Another point to be noticed is the fact that as far back as the eleventh century B.C. time was measured in China by the *clepsydra* or water-clock. In the Western Han this was graduated metrically to one hundred *k'ê* or sections for night and day, and would thus correspond to the sun-dial, whereas, later on it was graduated to ninety-six *k'ê* which made twelve (two-hour) periods for night and

Fig. 2.—Ink-squeeze of fragmant of stone sun-dial (C). Location of this is now unknown.

day, in what was called the *shih ch'en* cycle of time. When and why this superseded the hundred-section system of the old diurnal cycle seems not to be known, but it retained the *k'ê* as the name for a section.

On dial A the circles, the segmental lines, the numerals, and various other lines, are marked with the greatest precision (Fig. 7). On dial B the circles, the segmental lines and the numerals are also very accurately placed and incised, but the other lines are very crudely carved, and give the appearance of having been applied afterwards by an unskilled hand (Fig. 1). These various lines on both dials of are great astronomical interest, and it seems they also link the dials to astrological uses and ceremonies, as may be seen

in the so-called "T L V" mirrors which date from the third century B.C., and the diagrams on the stone frescoes of Hsiao-t'ang Shan (A.D. 128) (Plate XIII) and Wu Liang Ssu (A.D. 149) (Fig. 3). The mirror gets its name from the T which is attached to the central square design of the dial, the L which adjoins the circumference of the circle on the four sides, and the V which is found in the square corners of the dial.

One of the earliest T L V mirrors is that from Shou Chou (Plate XIII) which would date about the middle of the third century B.C.

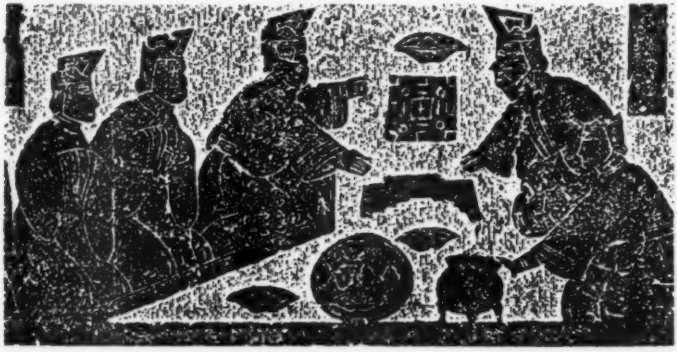


Fig. 3.—Ink-squeeze of section of stone frieze of Wu Liang Ssu, Shantung, dated A.D. 149. The setting is that of a ritual ceremony, with a square object in the centre, having the lines but not the circles of the sun-dial.

This particular mirror contains a sun connotation in the figures of two dragons around the central knob. A bronze lamp of Han times, in the form of the *Fu-sang* or sun-tree with two dragons at its base trying to swallow the sun-tree, is now in the Royal Ontario Museum. (See *Illustrated London News*, Jan. 11, 1936, pp. 60-61). This legendary depiction is found nowadays in the pair of dragons chasing the sun pearl. In the mirror the central knob around which the two dragons move would take the place of the central gnomon of the dial. Other forms of T L V designs are found on mirrors such as that of Fig. 4 which might possibly date about the second or first century B.C.; and Figures 5 and 6 which also might come

into the first century B.C. The latter (Fig. 6), has a design of a very intricate composition which includes a quadrefoil design, two groups of eight and nine small nipples respectively, and eight zodiacal animals, as well as peripheral borders of rope, zigzag and

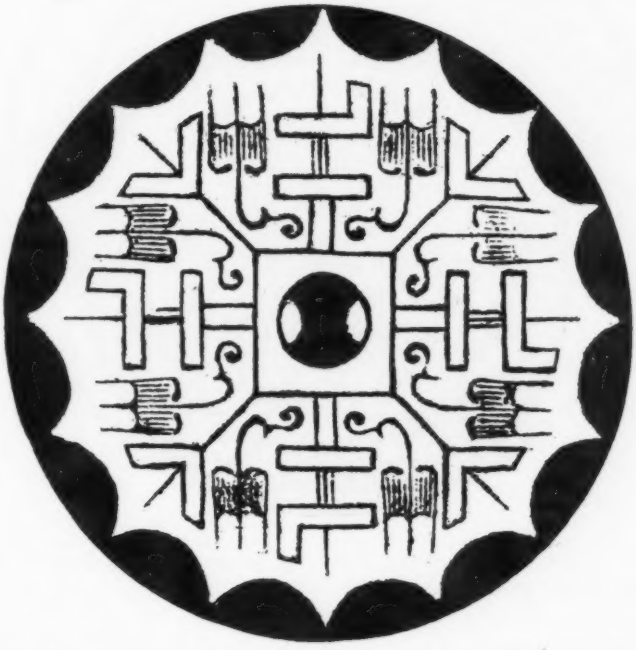


Fig. 4.—Ink-squeeze of design on the back of a bronze mirror, showing T.L.V. emblems. Probably of the second century B.C. Diameter 5 inches.

cloud designs. Amongst the animals may be noticed the animals of the four cardinal points, that is the conjoined snake and tortoise on the north, the dragon on the east, the red fowl on the south and the tiger on the west. These are to be found on the right of each cardinal point when looking from the circumference to the centre. A complementary animal in each case is found on the left,

being respectively the hare, the monkey, the dog and the rat. It should be remembered that these designs are on the back of the mirror, the other side being the plain reflecting surface.

Mirrors were used as charms and talismans, both in dwellings

Fig. 5.—Ink-squeeze from the back of a bronze mirror, probably second century B.C., showing T.L.V. designs. Diameter 4 inches.

and on the person, and were commonly placed in coffins and tombs at funerals.

The sun-dial diagram is found on at least two carved stone frescoes of the second century A.D. In the Hsiao-t'ang Shan fresco (A.D. 128) two men seem to be playing chess (Plate XIII) and the diagram on the four-sided pedestal is that of the sun-dial. In the Wu Liang Ssu fresco (Fig. 3) the setting seems to be that for a ritual ceremony, for ritual vessels are laid out with wine cups and food offerings. Prominently in the centre is a square object with the lines, but not the circles, of the sun-dial. Recurrent anniversary

Fig. 6.—Ink-squeeze of design on the back of a bronze mirror. Probably of the first century B.C. Diameter 6¾ inches.

Besides the T.L.V. designs, there are eight zodiacal animals, and two groups of nipples. The bird form seen at the lower right hand point is that of the Red Bird of the South.

or periodic sacrifices, such as that of the solstices, were the common practice from very early times, and the dial would be a most natural object in this setting, for as mentioned above the T L lines on the dial would seem to point to a solstitial connection (Fig. 8).

William C. White
Keeper of the Far Eastern Collection
of the Royal Ontario Museum.

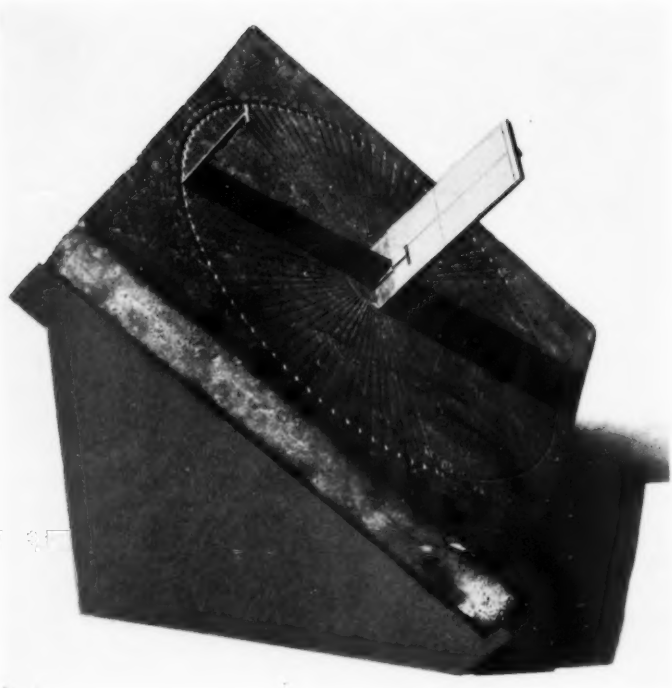
II. THE ASTRONOMICAL SIGNIFICANCE OF THE DIAL.

IT is difficult to know just when sun-dials were first used. It is certain that some form of gnomon was devised at a very early date. A description of the gnomon appears in the "Chou-pi", an ancient Chinese work attributed to about 1100 B.C., and there are references to it in both the Egyptian and Chaldean records. One of the early references to some form of instrument for marking out the time by the sun dates from about 700 B.C. and is found in the Bible, Isaiah XXXVIII, 8, though it is not certain that a dial is referred to here. The earliest dial which has been preserved is a simple "L" shaped Egyptian dial of about 1500 B.C., now in the Berlin museum. The hemispherical and hemicycle forms of dial came into use in Greece and Rome about 300 B.C. and the plane dial in Europe seems to have originated sometime near the beginning of the Christian Era. More complete accounts of early dials will be found in "The Book of Sun-Dials" by Eden and Lloyd, 1900; and in the Enc. Britannica, 14th edition.

Up to the present records of Chinese sun-dials have dealt only with relatively modern examples, presumably introduced from the west, and using the Chinese 12-hour division of the 24-hour day. The unique example of an ancient Chinese dial, secured by the Rt. Rev. W. C. White, D.D., for the Royal Ontario Museum of Archaeology, and discussed by him in the accompanying article, is therefore of peculiar interest. Since the gnomon is missing, the exact method of using this dial is not self-evident and Bishop White suggested to the writer that it might be possible to come to some conclusion concerning its probable use from astronomical evidence on the dial itself.

The object in question (Plate XII), is a slab of grey limestone 11.2 by 10.8 inches in size and 1.2 inches thick. Inscriptions are engraved into the stone and appear on one face only at the centre of which is a tapered hole. All markings on the dial have been reproduced in the scale drawing (Figure 7) and the dimensions of these, as found by measurement with a steel rule and eye lens, are given in Table 1. The chief feature of the dial surface is a circle, inscribed with remarkable accuracy about the centre. About two-

PLATE XIV



The Chinese sun-dial with a reconstruction of the suggested form of gnomon in place.

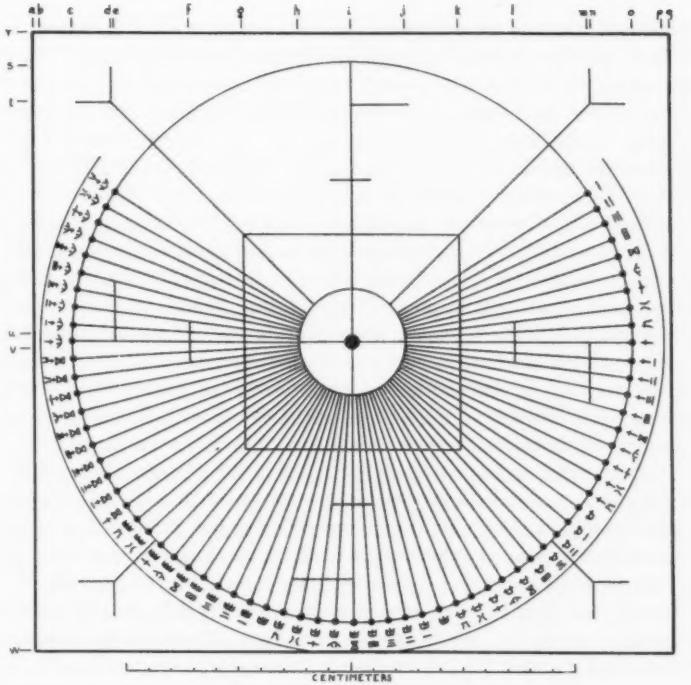


Fig. 7.—The diagram on the dial face.

TABLE I.—DIMENSIONS OF THE DIAL

Side of stone slab—*aq*	284		mm.
Side of stone slab—*rw*	275		
Thickness of stone slab	30	*	
Diameter of incomplete circle—*bp*	278.0	±.6	
Diameter of main circle—*co*	250.45	±.10	
Distance between outer gnomon marks—*em*	211.6	±.5	
Distance between inner gnomon marks—*fl*	144.4	±.6	
Side of square—*gk*	96.0	±.3	
Diameter of small circle—*hj*	47.3	±.1	
Diameter of central hole at top—*uv*	6.5		
Depth of central hole	15.0		
Length of long diagonal lines	127.3		
Length of short diagonal lines	25.7		
Length of lines on ends of diagonals—*st*	15.9		

*mean deviation of a single measure.

thirds of this has been divided into segments, each 3.6 degrees in length, that is one-hundredth of the complete circumference. These divisions are marked by small circular depressions in the stone about 3 mm. in diameter and 2 mm. in depth. They are numbered from 1 to 69 in a clockwise direction in the Chinese "small seal" characters which were in general use in the 2nd and 3rd centuries B.C. There are no other characters on the dial. Reference to Figure 7 will show that, in addition to radial lines, diagonal lines ending in small "V's", and a small circle and square, there are eight short lines on the dial which meet the two principal diameters of the large circle at right angles. These latter, which may for convenience be called "gnomon marks", are of interest as they are apparently meant to give certain information concerning the length of the gnomon or the shadow of the gnomon at the solstices, when the sun is in its extreme north or south positions. There are four inner and four outer gnomon marks, symmetrically arranged.

For use the dial was evidently placed in the plane of the equator since the numbered divisions are all equal and this is the only position in which they would correspond to equal intervals of time. In any other position the length of time corresponding to one division would vary not only throughout the day but also with the time of year and the dial would be very inefficient as a practical instrument. From what we can deduce of the astronomical knowledge at this period in China it was probably sufficient to make possible the setting of the dial in the plane of the equator. Moreover, the Chinese had for some centuries before the period of this dial used the *clepsydra*, or water-clock, which measured time in a unit called a *k'ê* which was one-hundredth of a day, this corresponding to the divisions on the dial. It should be pointed out here that this early use by the Chinese of equal units of time in measuring the day was far in advance of the western practice. European sun-dials divided the day from sunrise to sunset into 12 equal parts, the temporary hours, this practice resulting in long hours in summer and short hours in winter. It is believed that hours of equal length throughout the year, the equinoctial hours, were first introduced on western sun-dials during the 13th century A.D.

Returning now to a discussion of the Chinese dial there seems

to be no evidence on it to indicate the latitude for which it was constructed; in fact it is probable that it was a standard type made for use over a fairly wide range of latitudes. Apparent noon is numbered 35 on each of the three examples known so evidently it was a convention to start counting the hours of the day at about 3.50 a.m. This corresponds approximately to the middle of morning twilight at midsummer for the latitudes from 35° to 40° N. North of latitude 50° the sun rises before this time in June so that this value may be taken as an upper limit of the latitudes for which this dial was constructed. It is interesting to note that the first mark is numbered one, there being no zero. In an ancient Chinese division of the night into watches it was considered to begin at dusk and end at dawn so that it seems consistent to find the hours of the day starting before sunrise.

Once we decide that this dial was used in the plane of the equator then we must assume some kind of secondary gnomon or plate to catch the shadow of the principal gnomon since the dial face will be in shadow from September to March when the sun is south of the equator. If the gnomon which casts the shadow is considered to be at the centre of the dial it must be fairly high to catch the sunlight at the winter solstice and the secondary gnomon must be higher still, making the instrument out of proportion and somewhat inconvenient to use owing to the fact that the dial face is inclined at a considerable angle to the horizontal. A neater and more practical arrangement is to consider the shadow casting gnomon as moved around the circumference of the large circle till its shadow falls on a plate at the centre of the dial. This method of lining two objects up to get the hour angle of the sun is found in other ancient Chinese astronomical instruments. With the above arrangement the noon mark on the dial, No. 35, would be placed to the south rather than to the north as is the case with modern sundials.

We must now consider the possible significance of what I have called the "gnomon marks" on the dial with respect to the height of the gnomon. All distances indicated on the dial by any of the markings were tabulated and then combined in pairs to see if any gave evidence of an angle corresponding approximately to 23.5 degress, the inclination of the ecliptic to the equator. A significant

ratio seemed to be the distance of the outer gnomon marks from the centre of the dial (ei) to the distance of the inner gnomon marks from the circumference of the main circle (cf). This ratio is exactly equal to 2. Now the first distance placed over the diameter of the main circle (ei/co), and the second placed over the radius of the main circle (cf/ci), are each equal to the tangent of 22°.9.

We can visualize a fairly simple arrangement for indicating the solstices by erecting a shadow-casting gnomon at the circumference of the main circle, height equal to the distance of the inner gnomon marks from the large circle; and a secondary plate or some device to catch the shadow at the centre of the dial, height equal to the distance of the outer gnomon mark from the dial centre. This development is illustrated in Figure 8. Now, with the dial in the plane of the equator and the gnomon moved so that its shadow falls centrally on the plate, the top of this shadow will reach the top of the plate at the winter solstice, the centre of the plate at the equinoxes, and the bottom of the plate at the summer solstice. The inclination of the ecliptic indicated by the above ratios is 22°.9 while it is known to have been about 23°.7 in 200 B.C. However, the value 22°.9 is found by assuming the face of the plate exactly at the centre of the dial and this is unlikely when we consider the necessity of a central bar to pivot on. If the face of the plate was just 7 mm from the centre then it would agree with an angle of 23°.7. In practice the gnomon and plate were probably connected along a radial line perpendicular to the plate and formed of a single piece of bronze. This would pivot on a central bar perpendicular to the dial face and supported in the hole at the centre. This bar might either have formed part of the plate, in which case it would have turned in the hole in the limestone, or it might have been a separate piece of bronze fixed firmly in the dial face with the plate coupled to it and turning about it. The top of the gnomon quite possibly was marked by a small horizontal bar which was a form known to have been used in large Chinese gnomons of a much later date. To read time from the dial with the arrangement suggested above one would move the gnomon till its shadow appeared centrally on the plate and then the value directly below the gnomon would indicate the $k'\hat{e}$. The time of year would be shown by the height of the top of the shadow on the plate. Plate XIV shows the suggest-

ed form of gnomon in place on the dial the position of the sun corresponding to an hour and a half before noon near either the end of August or the end of April.

As noted previously the late Dr. Liu Fu published an article on this dial in the Journal of Sinological Studies, National University of Peking, vol. 3, no. 4, 1933, and he came to the same conclusion as the writer concerning the use of the dial in the plane of the

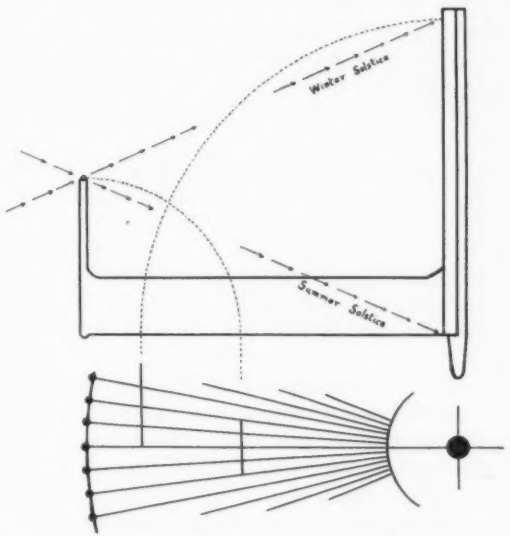


Fig. 8.—The development of a suggested form of gnomon.

equator. His measurements were made from rubbings, however, so that they differ somewhat from those given above which were made directly on the dial itself. Dr. Liu suggested essentially the same ratios given above as indicating the inclination of the ecliptic but considered that the shadow casting gnomon was at the centre of the dial and suggested a detached secondary gnomon in the form of a small rod which could be moved around the circumference of the main circle to catch the shadow of the central gnomon in the fall and winter. This arrangement has the advantage of requiring no secondary gnomon during half the year but it is open to the

disadvantage mentioned previously of necessitating awkwardly long gnomons. Two other points which should be noted in this connection are that the ratios on the dial face cannot be projected on to this system of gnomons in any simple way to show the solstices, and also that the use of a detached part for reading the dial does not seem to be in keeping with the general design of practical instruments of the former Han period. One must remember, howeve,r to keep an open mind concerning the exact form of the gnomon since the dial does not give us enough information to define it exactly and it will probably remain uncertain until further archaeological discoveries are made. I believe that the gnomon suggested in the present paper is fairly logical and practical but it should be considered as only tentative.

One other ratio on the dial should be mentioned as of possible significance. The length of the radial lines (ch) over the distance (cm) is exactly equal to the tangent of 23°.7, but to work this into any system of gnomons was found to be a little far-fetched. The other markings on the dial seem to have no special significance with regard to the gnomon. The square may have a symbolic meaning as the ancient Chinese represented the earth by a square and the heaven by a circle. The diagonal lines with the small right angles at the corners may have been used, as Bishop White has suggested, in lining up the dial in some way as they are similar to lines on other objects used for this purpose. The displacement of the outer gnomon marks to one side of the circle diameters may indicate the direction of diurnal solar motion or advancing hours. On Plate XII a minor mistake in the original drilling of the small depressions will be noted near 48 *k'ê* in the lower left corner.

In conclusion it may be said that, whatever the original form of the gnomon, it is evident that in this dial we have a practical astronomical instrument of a standard design, constructed with surprising accuracy considering the early date: and there seems little doubt, in view of the evidence which Bishop White has brought forward, that though the original scientific use of the accurate design on the dial face was gradually lost, the design itself remained for some centuries in a modified form as an integral part of ceremonial and astrological symbolism.

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METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Meteor Observations made in the Transvaal

It is a pleasure to be able to report in these columns some meteor observations made in the southern hemisphere where, with the single exception of New Zealand, all too little work has been done in this field.

Mr. M. Druker of Doornfontein, Johannesburg, Union of South Africa, observed meteors visually on several nights in July and on one in September of this year. Meteors were timed, general positions in the sky noted, and magnitudes and colours estimated. Since plots were not made individual meteors could not be assigned to any given radiant and the results below therefore represent the total number of meteors seen in the interval by a single observer who was timing and noting some detail about each meteor.

Date (1938)	S. Afr. S.T.	Weather Factor	Meteors Observed	Hourly Rate
July 22-23	19.30—20.40	9	9	8
	21.35—22.45	8	9	8
July 23-24	17.32	..	1	..
July 24-25	20.00—20.45	8	26	35
July 25-26	21.20—21.55	8	15	26
July 27-28	22.20—22.55	10	15	26
September 28-29	20.55—21.45 (less 8 m.)	3	5	9

Magnitude Distribution

Mag.	−3	−1	0	1	2	3	4	5	Total	Mean Mag.
Meteors	1	1	1	1	5	16	35	18	78	3.6

Colour Distribution

Colour	r	ry	rw	y	w	gy	g	y then g
Meteors	21	16	5	16	8	7	6	1

On examination of the above table the high rates near the end of July, due to the Aquarid shower, are quite marked. The one meteor seen on July 23-24 was of magnitude −3, train duration 3 sec., green with a suggestion of yellow, and appeared 4 degrees above the eastern horizon. Its zenithal magnitude must have been very bright, possibly −8 or brighter. The average magnitude of the other meteors seen was quite faint. Mr. Druker estimated colours for the metors observed and the distribution of these has also been tabulated. The estimation of the colours of meteors is admittedly difficult and subject to considerable personal equation. Such records, made by someone with good colour vision are, however, of definite value. In the colour distribution given above the red shades seem to definitely predominate. This is the normal result if we except white which is often given when no marked colour can be detected owing to faintness or poor observation.

It is to be sincerely hoped that we receive more observations from South Africa and that the above report is only the beginning of systematic meteor work carried out in this part of the world.

P. M. M.

REVIEW OF PUBLICATIONS

Materie im interstellaren Raume, by Wilhelm Becker. (Fortschritte der Astronomie, Band 1). 78 pp., 6¼ x 9¼ ins., Johann Ambrosius Barth, Leipzig, 1938. Price RM 7.50, unbound.

Under the auspices of the Astronomische Gesellschaft, and the editorship of Professor P. ten Bruggencate of the Astrophysical Observatory of Potsdam, a new series of astronomical monographs is being published. These monographs will be written by experts in various branches, and are intended to present, in each case, a unified survey of the present state of knowledge about some particular field of research. The purpose is to allow astronomers more easily to keep up to date their knowledge of the rapid and widespread developments in research outside their own fields of specialized study.

The first volume, by Dr. W. Becker, of Potsdam, is on Interstellar Matter. He devides his study into five chapters, dealing with dark nebulosity, general galactic absorption, selective absorption, optical density of the absorbing layer, and wave-length distribution of the absorption. Each of these subjects is surveyed in a descriptive manner, the observational bases are discussed, and conclusions drawn as to the results.

The material is well presented. A tabulation of the data on the individual absorbing nebulosities, and a bibliography of 127 references to work on the subject of interstellar absorption should prove of great convenience. It should however be noted that the interstellar matter here discussed is almost entirely that which manifests itself by general absorption and by space reddening; the whole fascinating field of highly selective absorbing matter in space —that which produces the stationary lines of sodium, ionized calcium, and the other elements more recently studied—has been practically excluded from this book. While based on observations of a quite different type, it would seem that this subject could have been included in a discussion of interstellar matter.

Further monographs planned for this series deal with Theories of Cosmology and Convection and Turbulence Effects in the Stars.

F. S. H.

Astronomy, by Robert H. Baker. 527 and x pages, 5¼ x 9 in. Third Edition. N.Y., Van Nostrand, 1938. Price $3.75.

The first edition of this book was published in 1930, the second in 1933, and now in 1938 we have the third. This statement is sufficient evidence that the work fills a definite want and that the author endeavours to keep it abreast of astronomical research.

It is intended for university and college students. In recent years there have been many important investigations in astronomy which have provided new results for the physicist and fresh viewpoints for the cosmic philosopher. A large number of these researches and their implications are included in this edition, and yet Professor Baker, by wise elimination and by rewriting some paragraphs, has avoided any appreciable increase in the number of pages of the book.

In this edition the questions at the ends of the chapters have been expanded, the star-maps have been improved, and a number of late photographs have been introduced. Since the greatest developments in astronomical knowledge relate to the galactic system the greatest changes in the book are in the portion devoted to that subject.

By using heavier and more highly calendered paper the multitude of half-tone pictures in the book have been rendered more pleasing, although many of the line-drawings are made heavier and not so satisfactory. It is unfortunate that the thickness and the weight of the book have necessarily been increased but this is freely excused when one sees the finely printed pages.

C. A. C.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Orbits of Jupiter's Satellites X and XI

Orbits have been computed for Nicholson's two new satellites of Jupiter, and are published in Harvard Announcement Cards 460, 461, 462. Dr. Paul Herget's retrograde orbit for Jupiter X mentioned in the October Journal has proved to be fictitious. His new orbit is direct, and agrees well with recent orbits by Dr. R. H. Wilson, Jr., of Mount Wilson, and Miss P. E. Fell and Miss R. White, of the University of California, based on observations on July 6, July 27-29, and August 25. Dr. Herget has also published an orbit of Jupiter XI, based on Nicholson's observations of July 30, August 25 and October 2.

The elements of Herget are as follows:

	Jupiter X (*Direct*)		*Jupiter XI* (*Retrograde*)	
Epoch, 1938	July 27.3128 U.T.		Aug. 25.2575 U.T.	
Mean anomaly, M,	211°.0221		66°.38825	
Mean angular motion, n,	1°.382030		0°.519890	
Semi major axis, a,	0.078601 a.u.		0.1508336 a.u.°	
Period, P,	260.5 days		692.5 days	
Inclination, i,	28°.266		163°.377	
Long. ascending node, Ω	82°.507	1950.0	231°.753	1950.0
Ascending node to perihelion, ω	247°.044		127°.948	
Eccentricity, e,	0.13244		0.20678	

The orbit of Jupiter X is thus very similar to those of Jupiter VI and VII; the retrograde motion of XI is paralleled by the retrograde motion of Jupiter VIII and IX. Its period, distance and eccentricity also are more nearly like those of the two outer satellites.

F. S. H.

The Aurora—its Audibility

Further evidence regarding sound heard at the time of an auroral display has been received. The writer of the following note is Miss E. M. Monro and the place of observation was on Lauder Avenue, near Regal Road, at the top of a hill north of Toronto. Miss Monro's statement:

On Tuesday, September 27, at about 10.30 p.m., I was asked to come out to see the remarkable auroral display. We stood on the lawn at the rear of the house, the position being shielded from street noises by houses, shrubbery and trees. The night was very still and at once my attention was drawn by a peculiar crackling noise. It was faint, but I heard it very distinctly—a sound such as is made by the leaves of trees when moved by a light breeze. I asked what the sound was and looked up to the nearby trees and to my amazement not a leaf was stirring. Against the strong light in the sky, I could see that the leaves were motionless. No air movement could be felt when I held up my hand. My hearing is rather acute. My fellow observer, whose hearing is less acute, could hear no sound, but I heard it distinctly. It may be of interest to note that at this time the sky overhead and farther south than the position of Jupiter was covered with auroral light, but there was none in the northern part of the sky. When more than half an hour later we went out again, the appearance was much changed. There were much more vivid colours and a brilliant display in the northern part of the sky. At this time I could hear no sound such as I had heard before.

The above statement was forwarded by Rev. Dr. D. W. Best, secretary of the Toronto Centre of the R.A.S.C., and he adds these remarks:

I should mention that her statement seems to me to have value in view of the fact that on the first occasion, when she heard the sound, it did not occur to her to attribute it to the aurora. She was in fact looking for any other source—chiefly the movement of leaves in nearby trees; and, finding them motionless, was much puzzled and enquired of me what the sound could be. I then mentioned to her that some observers believed they had heard the aurora make such a sound as she had described. On the second occasion, perhaps three-quarters of an hour later, with this information fresh in her mind, she was not able to hear the sound. This would seem to rule out the usual explanation—that her experience was purely subjective. She was impressed by the absence of light in the north part of the sky on the first occasion, expecting that "Northern Lights" should be found in the north.

C.A.C.

Correction to Radio Talk

Dr. W. E. Harper writes: In the July-August issue of the Journal, in discussing "Big Stars", a value of four instead of thirty-three was used (page 318) for the intrinsic luminosity of the sun as compared with Betelgeuse. More accurate values of temperatures would yield the ratio 26:1. The error was noted by Mr. Karl Buckthought, who has my thanks for drawing the slip to my attention.

MEETINGS OF THE SOCIETY

AT EDMONTON

January 13, 1938.—Mr. Douglas Crosby gave a paper on "Solar and Lunar Halos". He showed pictures of ice crystals, and by means of models illustrated the tendency of plates and columns falling through the atmosphere to form definite alignments, so producing by reflection and refraction of light the various kinds of halos. The speaker classified the types of sun-dogs, halos, circum-zenithal arcs etc., produced by reflection, the parhelic circle and dogs formed by refraction, and the coronas, Brocken spectres, etc., caused by diffraction.

February 10, 1938.—The main feature of this meeting was the showing of three astronomical sound films made by the Electrical Research Products Inc. (Erpi) under the supervision of Dr. Bartky. These were obtained on loan from the library of the University of Wisconsin. The titles were (1) The Moon, (2) The Solar System, (3) Exploring the Universe. Following the showing, which took half an hour, comments on the films were made by different speakers, Mr. Keeping on the first, Dr. Campbell on the second, and Dr. Gowan on the third. The films were then run through a second time, so that members could take special note of points brought out in the comments.

An exceptionally large number of members and visitors, close on 100, turned out for this special programme.

March 10, 1938.—Miss Jean McDonald read a paper on "The Planets", based on articles by H. N. Russell in "The Scientific American". She described how the different planets of the solar system appear to us, and then how the earth, as a planet, would appear to observers, gifted like ourselves, on Mercury, Venus, Jupiter and the moon.

To an observer on Venus, the earth would be a most brilliant white star, of magnitude as high as –6.5, and even the moon would appear as bright as Jupiter does to us, so that the relative motion of planet and satellite would be conspicuous to the naked eye. Clouds on the earth would appear in a telescope as brilliant white belts, desert areas as dark regions, forests and oceans probably a dull blue. Owing to the prevalence of cloud it would probably be difficult to deduce from the observed appearance any definite period of rotation.

April 14, 1938.—This meeting was described in the notice sent to members as an "astronomical pot-pourri".

The president, Mr. C. G. Wates, gave an account of the theory and construction of a "richest field" telescope, emphasizing the beauty of parts of the Milky Way as seen through such a telescope, with as many as 700 stars visible

in the field at one time, and pointing out that nevertheless no such instrument is obtainable commercially.

Short talks were then given by Mr. Coulman, Mr. Keeping and Dr. Gowan on the ten transparencies of astronomical subjects which were presented by the Centre to the University of Alberta in 1936 and which are permanently displayed in the Arts Building.

Dr. Campbell made on behalf of the Centre a presentation to Mr. F. S. Simpson, a charter member and past president, who was shortly leaving Edmonton and retiring to Toronto. Dr. Campbell stated that it was largely through the interest in astronomy manifested by Mr. Simpson and two or three others that the Edmonton Centre was originally founded, and he recalled also that it was during Mr. Simpson's tenure of the chair that the transparencies were obtained. The gift consisted of a copy of Moulton's "Consider the Heavens", suitably inscribed and bearing the signatures of all the officers and councillors of the Centre for 1938.

Mr. Simpson thanked the Centre and then gave a short talk on the philological side of astronomy, mentioning such things as the original meaning of the word "pole", the origin of the name "Charles's Wain" for Ursa Major, and the etymological connection of the words "arctic" and "ursa".

May 5, 1938.—Mr. E. S. Keeping gave an account of the British Polar Year Expedition of 1932-33, some of the results of which have recently been published in two handsome volumes, with a third volume, dealing particularly with the auroral results, still to come.

The speaker recalled the occasion in June, 1932, when the party of six British scientists, led by Dr. J. M. Stagg, were given a dinner by the Edmonton Centre when they passed through the city on their way to the station at Fort Rae on Great Slave Lake. Mr. Keeping described the nature of the work and the difficulties that had to be overcome in making continuous records of meteorological, magnetic and electrical phenomena in primitive log huts and in a winter climate such as that of Fort Rae. He summarized the results obtained in the different fields of work as set forth in the published volumes.

To illustrate the auroral work some slides were shown made from photographs lent by Dr. Stagg for the occasion. One of these, a double photograph taken simultaneously from the present Fort Rae and the Old Fort for the purpose of determining the height of the aurora, was made into a stereogram for viewing through an ordinary stereoscope.

E. S. KEEPING, *Honorary Secretary.*

AT TORONTO

April 5, 1938.—The regular meeting was held in the University of Toronto at 8 p.m.! Mr. E. J. A. Kennedy in the chair.

Mr. John R. Buliung, 46 Seventh Street, New Toronto, was elected a member of the Society.

The paper of the evening on "The Aurora" was given by Dr. B. Haurwitz of the Meteorological Service. In a highly interesting address, illustrated with lantern slides, the lecturer, after describing briefly various auroral forms, went on to speak more at length of the frequency of displays, the close relation between aurorae, magnetic storms, and solar activity; also of the measurement of auroral heights, which Störmer found in Norway to be from 80 km. to 650 km. the corpuscular theory. According to this, aurorae are caused by electrically charged particles from the sun, which enter the atmosphere and cause the luminescence of the upper rarified atmosphere in a manner similar to cathode rays in a discharge tube, explaining successfully many phenomena in aurorae and magnetic storms. A discussion followed in which Messrs. J. R. Collins, S. C. Brown, R. H. Combs and others took part, Dr. Haurwitz kindly answering many questions. On motion of Dr. Best the most cordial thanks of the meeting were conveyed to the lecturer.

Mr. Duncalfe gave a lucid explanation of solar and sidereal time which was much appreciated.

Mr. J. R. Collins called attention to the predictions of phenomena and referred to the recently discovered facts about the star ε Aurigae, whose diameter seems to be about 3,000 times that of the sun.

April 19, 1938.—The regular meeting at the usual place and time; Mr. E. J. A. Kennedy in the chair.

Mr. A. Harris, c/o C.P. Railway, Guelph, Ont., and Mr. W. J. Chisholm, c/o C.P. Railway, Guelph, Ont., were elected members of the Society.

The speaker of the evening was Professor C. Barnes of the University of Toronto whose subject was entitled "Is the Universe finite?" Professor Barnes held the close attention of the audience as with clartyi he discussed Euclidian and non-Euclidian geometries with their various implications. If Euclidian geometry is valid you can have an infinite universe, otherwise a non-Euclidian geometry can give a finite universe without boundaries, as illustrated in the geometry of the surface of a sphere. Professor Barnes kindly answered a number of questions and on motion of Mr. Duncalfe the hearty thanks of the meeting were extended to the lecturer.

Dr. J. F. Heard concluded his series of ten lectures on the elements of astronomy, his subject for the evening being "Clusters and Nebulae". Both open clusters and globular clusters belong to our stellar system. The globular clusters form together an ellipsoidal-shaped system which occupies much the same space as the stellar system. The galactic nebulae are classified as planetary, diffuse and dark nebulae. Nebulous material is a mixture of gases and particles, extremely tenuous. The extra-galactic nebulae are so numerous they might be photographed by the millions and most of them fall into two classes, elliptical and spiral. The nearer spirals are resolved in part into individual stars, are disc-shaped, are in rotation, are comparable in mass, size and brightness to the galaxy, and contain variable stars, novae, and globular clusters. They seem to be uniformly distributed throughout space.

The elliptical nebulae, without apparent organized structure, are generally believed to be galaxies in the making.

On motion of Mr. S. C. Brown, it was resolved to place on record an expression of warm appreciation of Dr. J. F. Heard's whole series of lectures.

D. W. BEST, *Recorder.*

AT VANCOUVER

May 1, 1938.—The fifty-sixth regular meeting of the Vancouver Centre was held at the University of British Columbia, and was preceded by the annual Members' Dinner, held at 6.30 p.m. in the University cafeteria.

The president opened the meeting by calling on Mr. H. W. Fowler for the half-hour talk on 'The Outer Planets". (This was the last of the 1937-38 series of such talks on the general topic "The Solar System".)

By way of introduction, it was pointed out that these planets fall into a natural grouping on account of both the method and the comparatively recent time of their discovery. The speaker gave an outline of the discovery of Uranus by Herschel, and listed the chief facts known about the planet and its satellites. The famous story of the discovery of Neptune was then referred to, and the chief physical facts of that planet were mentioned.

The speaker then outlined events leading to the discovery of Pluto, for a period of about thirty years preceding that discovery. He then related in considerable detail the circumstances of the discovery of its image on plates taken at Flagstaff, Arizona, on Jan. 23 and 29, 1930. A summary of our present knowledge of this planet was then given.

Reference was then made to the Greek Mythology which has served as a source of names for many members of the solar system.

Brief explanations were given regarding some of the methods of planetary research which have yielded much of the information now available regarding conditions on distant planets. Among these were mentioned four methods of determining rotational periods, some problems in determining atmospheric compositions and conditions by spectroscopy (particularly, the recognition of telluric lines and bands), and the determination of surface temperatures. The experimental methods of determining the latter by means of thermocouples or bolometers were described, and some factors involved in the theoretical prediction of these temperatures from calculations based on the sun's radiation constant, Stefan's Law, and other data, were given.

The speaker concluded with a brief bibliography of some of the sources of information concerning the topics covered.

Brief reviews of the half-hour topics of the 1937-38 season were given by those contributors to this series who were present. In response to considerable questioning by the members, these speakers considerably supplemented and augmented the material already given by further information or explanations.

H. W. FOWLER, *Secretary.*

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General Index to the TRANSACTIONS of the R.A.S.C., 1890-1905, and the JOURNAL, Vols. 1 to 25, 1907-31.

Compiled by W. E. Harper, Assistant Director, Dominion Astrophysical Observatory, Victoria, B.C., 122 pages. Price $1.00 postpaid.

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